

REMARKS

In view of the above amendments and following remarks, reconsideration of the rejections contained in the Office Action of October 25, 2006 is respectfully requested.

Claims 1 and 17-27 were rejected as being unpatentable over Tausig et al., U.S. Patent No. 6,311,759 (Tausig) in view of Kemnitz, U.S. Patent No. 5,778,533 (Kemnitz). However, it is respectfully submitted that the present invention is not disclosed or suggested by these references, whether considered separately or in combination.

The present application at this time includes two independent method claims, claims 1 and 26. Both have now been amended at this time to refer to the piston as being formed from a steel material. In addition, claim 26 has been amended to recite particular aspects of the present invention which will be discussed below.

That is, claim 26 recites the additional step of casting and cooling a steel material. The step of heating heats the steel material so as to bring the steel material to an intermediate temperature between its solidus temperature and its liquidus temperature. At least one of the casting, cooling and heating comprises obtaining a globular primary structure of the steel material. The steel material is then shaped by thixoforging the steel material at the intermediate temperature so as to form the piston. The globular primary structure of the steel material is obtained without an operation of globulization separate from the casting, cooling and heating.

These amendments are supported by the original specification. Note the discussion beginning from the third to last line on page 4 of the specification, and the first two paragraphs on page 5 of the specification.

It should be primarily emphasized that the Tausig reference deals substantially only with light alloys, and mainly aluminum alloys, as can be seen from the examples that are given by Tausig. While steels are briefly cited in Table 1, there is nothing within Tausig that would disclose to one of ordinary skill in the art sufficient information to enable the manufacture of a steel piston without undue experimentation. The thixoforming of light alloys is relatively easy, because these alloys have a low melting temperature. However, for steels the process is much more complicated because of their higher melting temperatures. Note that in column 5, lines 44-50 of Tausig, casting preferably

takes place in Tausig in a steel mold. This would be quite difficult if the cast alloy itself was steel, and not a light alloy with a low melting point such as aluminum.

Furthermore, Tausig has in essence four steps, which will be discussed in detail.

First, Tausig begins with a material that has been previously obtained by conventional means, such as being cast in roll bars or billets or ingots cut into slugs having a known composition and known liquidus and solidus temperatures. See for example column 2, lines 65-66; and column 6, lines 52-54, which lead one to the understanding that the aluminum alloy was already available before being remelted in a subsequent second step that will be discussed below. See also, for example, column 7, line 27, stating that the "liquidus-cast 2618 slugs were reheated", which slugs are the products from which the process begins.

In a second step according to the operation of Tausig, feedstock is made according to a process that involves remelting the slug as described above in order to bring the slug to a liquid state. Its temperature is then reduced down to a temperature between the liquidus temperature and the liquidus temperature plus 10°C. It is cast at this temperature until complete solidification. The second step is part of the basis of the Tausig invention, and is what gives the feedstock a globular structure that is helpful in the subsequent steps of Tausig. The second step of Tausig is not present and not required in the present invention.

This second step is described at a number of locations in Tausig. For example, at lines 32-35 of column 4, Tausig states that "it has been surprisingly discovered that the solidified metal can be partially remelted and thixoformed and that significant benefits accrue in the thixoforming process." The thixoforming takes place in later steps.

At lines 38-41 of the same column, Tausig states that "thixoforming can be easily conducted using high solids fraction, low die temperature and low forming speed whereas other materials would require lower solids fraction and higher forming speeds to obtain similar results."

Further, in column 4, lines 54-57 Tausig states that "the solidified metal has been found to have an as-cast microstructure that contains independent globules separated by a phase of lower melting point material (normally eutectic phase)." (Emphasis added)

Performing this second step would be very difficult under industrial conditions. As Tausig notes in column 3, lines 41-58, temperature control becomes progressively more difficult as the volume of melt increases. With the assumption that a reliable temperature reading is obtained, a spatial temperature distribution or temperature uniformity within a volume melt is best measured by a number of probes that are distributed throughout the volume of melt. The discussion, continuing through line 21 of column 4, establishes that a complex temperature measurement device is necessary. While Tausig discusses in this part that Tausig's invention encompasses within its scope temperature control systems capable of achieving the desired accuracy and control, Tausig also notes that it does not form a part of the invention as such, and that Tausig believes that current temperature control techniques allow the molten metal temperature to be controlled to the accuracy required. However, the precision that is required for the temperature regulation by Tausig is in fact not obtainable under industrial conditions. Because the present invention does not require this second step, the present invention in fact readily simplifies the process as compared with Tausig and provides far better productivity as a result.

The solidified feedstock that is obtained in the above-described second step of Tausig is then again reheated in a third step. At this point, it is reheated to between its liquidus and solidus temperatures so that it is partially remelted. The feedstock has a globular primary structure as described in lines 57-64 of column 4. Tausig cites no particular requirements with respect to the reheating phase; the semi-solid material or slurry is obtained, containing both solid particles and liquid metal.

In Tausig, the temperature that is to be reached for forming an aluminum alloy can correspond to a solid fraction of 50 to 80% according to the examples described in Tausig. See column 5, lines 46-67, column 7, lines 27-28 and column 9, lines 5-6 and 27-28. By contrast, in the present invention, for thixoforging a steel alloy, a liquid fraction of 10 to 40%, corresponding to a solid fraction of 60 to 90%, is appropriate, as discussed in the specification.

A fourth step in Tausig involves the thixoforming of the metal that is obtained through the third step described above. With the aluminum alloys, the use of a ceramic die is possible, as described in column 7, line 30. However, this would not be possible with steel.

It is also noted that in Tausig, low deformation speeds of 0.1 to 0.2 m/s during thixoforming is considered advantageous. See column 6, lines 1-5, column 9, line 44 and column 10, line 2. However, these low speeds are disadvantageous in a practical industrial process. By contrast, with the present invention involving the thixoforging of steel, a high deformation speed is possible, allowing for an increase in productivity as compared with Tausig. Note for example the description in the present specification at the last three lines of page 4. Deformation speeds in accordance with the present invention can be on the order of 0.4 m/s, advantageous both for the final quality of the thixoforged part and plant productivity.

In accordance with the present invention as described in the specification, the method of making a piston involves primarily casting and cooling a steel a material. This starts from liquid steel that is cast either continuously or into ingots. The casting takes place most generally at temperatures that are at least 30 to 50°C higher than the liquidus temperature, i.e. in conventional conditions.

Optionally, the liquid steel can be stirred by electromagnetic means within the mold and during solidification, adjusting the cooling intensity. This can obtain a globular primary structure of the solidified bar, billet or ingot. If not done at this point, then the globular structure can also be obtained during the subsequent heating of the steel material to between its solidus and liquidus temperature prior to thixoforging.

Accordingly, with the present invention, a second step as described above with respect to Tausig, specifically obtaining the globular primary structure of a slug that is ready for thixoforging, is not required by the present invention. This is because the obtaining of the globular primary structure can be carried out during either the casting or cooling of the steel material or the heating to between the solidus and liquidus temperature.

An advantage of avoiding this second step that is required by Tausig is that such second step would be very difficult to carry out on relatively large industrial steel slugs. Obtaining, within the whole slug, a temperature that is regulated to a very precise level, between the liquidus and 10°C above the liquidus, would not be possible on a practical level in industrial conditions. Similarly, it

is not possible to reliably obtain such a narrow temperature range during casting of the steel bar/billet or ingot. The risk of solidification of the steel in the net casting nozzle is too high.

The liquidus temperature of the steel depends upon its composition. The greater the amount of alloying elements, the lower the liquidus temperature. However, even for highly alloyed steels, such as stainless steels, the liquidus temperature is very seldom lower than 1400°C, and can be as high as 1510°C. In the examples in accordance with the present invention, the temperature is about 1490°C, far higher than the 638°C of the aluminum alloy that is cited in Tausig.

Thus as has been discussed, with the present invention the second step as described by Tausig is avoided. The heating to between the solidus and liquidus temperatures can include obtaining the globular primary structure, and if it already exists, having been obtained during casting and cooling, as described, the heating speed can be controlled in order to further improve the globularity of the primary structure. Note the discussion in paragraphs 2 and 3 of page 5 of the original specification.

Independent claim 1 clearly distinguishes over Tausig because of its recitation of the piston being formed from a steel part cast in one piece.

Independent claim 26 recites a method of making a piston in which it is specifically recited that at least one of the casting, cooling and heating comprises obtaining the globular primary structure of the steel material. Further, the claim recites that the globular primary structure of the steel material is obtained without an operation of globalization separate from the casting, cooling and heating. Accordingly, both independent claims clearly distinguish over Tausig.

Kemnitz has been cited by the Examiner with a proposition of showing a one-piece steel piston. However, it does not otherwise cure the defects of Tausig as described above with respect to the methods that are reflected in each of independent claims 1 and 26. In particular, Kemnitz does not suggest to one of ordinary skill in the art that the process of Tausig could be used for the formation of a steel piston, because of the problems that are involved in manufacturing a steel product with the method of Tausig as described above.

Accordingly, it is respectfully submitted that all of the claims which are now pending in the present application clearly distinguish over Tausig and Kemnitz. Indication of such is respectfully requested.

In view of the above amendments and remarks, it is submitted that the present application is now in condition for allowance, and the Examiner is requested to pass the case to issue. If the Examiner should have any comments or suggestions to help speed the prosecution of this application, the Examiner is requested to contact Applicant's undersigned representative.

Respectfully submitted,

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